Referee 1

General comment

The paper investigates potential source regions and ice-related factors affecting size distributions and newly formed particles in Arctic based on measured size distributions during five cruises of I/B Oden in the summers of 1991, 1996, 2001, 2008, and 2018. The topic is of interest and suitable for the Journal. A few aspects should be made more clear in a revision step, see my specific comments.

We thank referee 1 for a constructive review. Our responses have been incorporated into the revised manuscript. Details are outlined below.

Specific comments

Section 2.2, lines 162-167. I understand that details are given in other papers, however, it would be useful to summarise here what instruments are used and their sizer range. In addition, if the different instruments have been compared one with the other and if size distribution of dried (i.e. low RH) air was measured.

All instruments were of the type electrical mobility analyzer. Relative humidities in the instruments were below 20%. Table 1 was complemented with lower and upper size limits pertaining to the different years. The time difference between subsequent expedition years was five to 10 years. Older instruments simply did not exist anymore for any direct comparison.

Table 1: Start and end date of hourly I/B *Oden* aerosol data utilized in this study in 1991, 1996, 200, 2008, and 2018, and the number of utilized hourly averaged distributions (Scans) ≥ 85° N after screening for possible ship pollution (total 2476). Also shown are the aerosol upper and lower size detection limits of the instruments used in the different expedition years.

Year	Start date	End date	Lower size limit (nm)	Upper size limit (nm)	Scans
1991	23 August	20 September	3	500	560
1996	1 August	9 September	5	600	715
2001	1 August	24 August	3	900	503
2008	10 August	3 September	3	800	411
2018	15 August	16 September	2.1	921	287

Section 2.3 Do you have any idea of the boundary-layer height. I was wondering if the arrival height was above or within the boundary layer.

The following clarification has been added to Section 2.3: The summer Arctic boundary layer is typically well-mixed and shallow (approximately 100 – 400 m), capped by a temperature inversion. At times, the inversion can be strong, especially when warmer air is advected from lower latitudes while the free troposphere remains stably stratified (Vüllers et al., 2021). An arrival height of 300 meters was chosen to ensure an optimal ensemble configuration, such that the receptor point is within the well-mixed boundary layer and close enough to the aerosol sampling height (25 meters above sea level). Additionally, the chosen receptor height reduces the risk of surface contact in the trajectory calculations caused by rounding errors or interpolation.

Figures 1 and 3 are very small to be readable. Authors should considering using a different layout. Suggestion adopted. Figure 3 (a-f) is now stretched over two figures, labeled Figure 3 (a-c) and Figure 4 (a-c).

Section 4. How the new particle formation events were determined? Or the discussion only consider small particles as newly formed?

The following text has been added to the above Line 301-302: The consideration is limited to new particle formation from the gas phase or from the division of sub-micrometer particles in their airborne state (Baccarini et al., 2020; Covert et al., 1996; Heintzenberg et al., 2006; Karl et al., 2013; Lawler et al., 2021; Leck and Bigg, 2010). A more detailed discussion will follow in section 5.4.

Figure 8 (now Figure 9). What is the meaning of the peak around 100% visible in each graph?

Sorry about our obscure formulation. The figure caption was extended to “When the probabilities of 0% and 100% open water lie outside the scale of a graph, the respective values are given as numbers in text boxes”.

Figure 12 (now Figure 13) and correlated discussion. It seems that there are very large differences between median values and average. This are likely due to large values influencing the average. However, the conclusions obtainable from median would be significantly different compared to those of average. Could you please comment in more detail this aspect. It could be useful to show a comparison of the incidence of new particle formation events in the two cases: melt and freeze-up periods.

In the text on lines 438-439, we write “the averages are strongly affected by individual particle formation events.” For more information on general features of small particle formation events, the following text has been added to lines 437-439:

The somewhat similar median distributions during “melt” and “freeze-up" were interpreted as representing the inner Arctic background, whereas individual particle formation events strongly influenced the averages. Particles with diameters under 30 nm, as shown in Figure 13, had particle number concentrations during “freeze-up" that were more than two orders of magnitude higher than during “melt,” especially for particles under 10 nm, indicating strong new particle formation. Based on aerosol particle number size distributions measured on I/B *Oden* covering the months of August and September of 1991, 1996, 2001, 2008, and 2018, a common characteristic of individual particle formation events is that the particle concentrations under 10 nm in diameter are often very low. Still, they can suddenly rise dramatically for 5-12 hours, reaching concentrations of several hundred to 1000 cm^{-3} in a background atmosphere with very low total aerosol numbers, typically around 100 cm^{-3} or less than 10 cm^{-3} (Covert et al., 1996), with weak subsequent growth before being scavenged by fog or rain (Karl et al., 2013; Leck and Bigg, 1999; Baccarini et al., 2020). Events with elevated 3–5 nm particles also show increased concentrations in other size ranges, less than about 30-50 nm, reaching up to 500 cm^{-3} for several hours (Leck and Bigg, 1999;2010; Karl et al., 2013). The occurrence of the events is especially notable during the freeze-up period.

The formation of numerous small particles below 10 nm in diameter is likely due to homogeneous nucleation originating from gaseous precursors, including iodic and sulfuric acids. These acids yield initial particle clusters that grow further by condensation, potentially supported by iodine acid or biogenic organic compounds vapors, or as a combination of production via the generation of marine polymer gels, which are released as small nanometer-sized (nano-granular) particles when clouds or fog droplets dissipate (Baccarini et al., 2020; Heintzenberg et al., 2006; Karl et al., 2013; Lawler et al., 2021; Leck and Bigg, 1999; 2010). The average number concentration of a prominent broad peak during “melt” was reported to involve emissions of biogenic particles, especially polymer gels, from the MIZ or open leads over the pack ice, and growth of pre-existing smaller particles through heterogeneous condensation of precursor gases like sulfuric and methane sulfuric acids from photochemical oxidation of DMS and aerosol cloud processing (e.g. Leck and Bigg, 2005b). As noted above, the very low aerosol concentrations over 300 nm diameter were shown to result from efficient scavenging near the MIZ.

References

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